MSFC-809

A Novel 24 GHz One-Shot Rapid and Portable Microwave Imaging System

(CAMERA)

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Outline

- Microwave Imaging
- Design and specific aspects
- Results
  - ✓ Real-Time Imaging
  - ✓ Transmission Mode
  - ✓ Reflection Mode
  - ✓ Image Processing
- Summary

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Microwave Imaging

- Microwave imaging is based on measuring the relative scattered field from an object over a known two-dimensional (2D) space.
- Objective is to obtain the coherent electric field distribution (magnitude and phase) over a known 2D space (i.e., mapping the field).
- Two available imaging methods:
  - ✓ Individual scanning probe
  - ✓ An array of probes

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MST Background

- Original MST paper:
  - J. H. Richmond, "A modulated scattering technique for measurement of field distributions," *IEEE Transactions on MTT,* vol. 3, no. 4, pp. 13-15, July 1955.
- Imaging system "camera" Supelec:
  - A. Franchios, A. Joisel, C. Pichot, and J.-C. Bolomey, "Quantitative microwave imaging with a 2.45-GHz planar microwave camera," *IEEE Transactions Medical Imaging,* vol. 17, no. 4, pp. 550-561, August 1998.
- Imaging system by PNNL, ...
  - 1st dimension: Linear switched antenna array
  - 2nd dimension: Mechanically scanned
- Others
  - Passive imaging

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Novelty of Approach

- An array of modulated probes provides for coherent electric field distribution measurement over a desired 2D space.
- Modulated probes tag the scattered signal, rendering specific spatial measurement capability.
- Traditional, minimally perturbing elements (e.g., sub-resonant dipoles) result in a compact array for field sampling and measurement, however they suffer from several drawbacks:
  - ✓ Inefficiency of the sub-resonant dipoles, places their scattered signal very close to the noise floor.
  - ✓ Mutual coupling among the dipoles can significantly limit system dynamic range.

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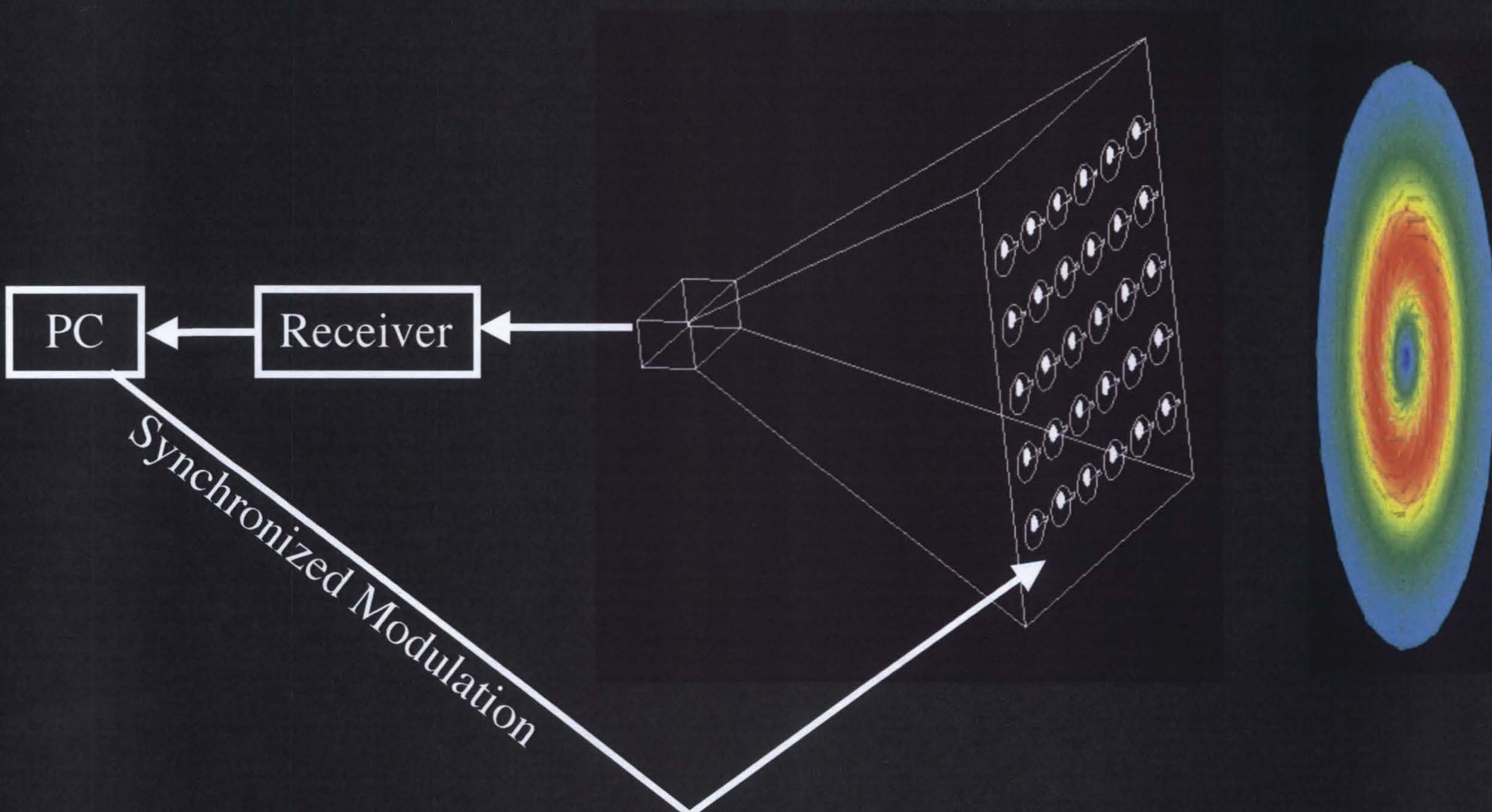
Novelty of Approach

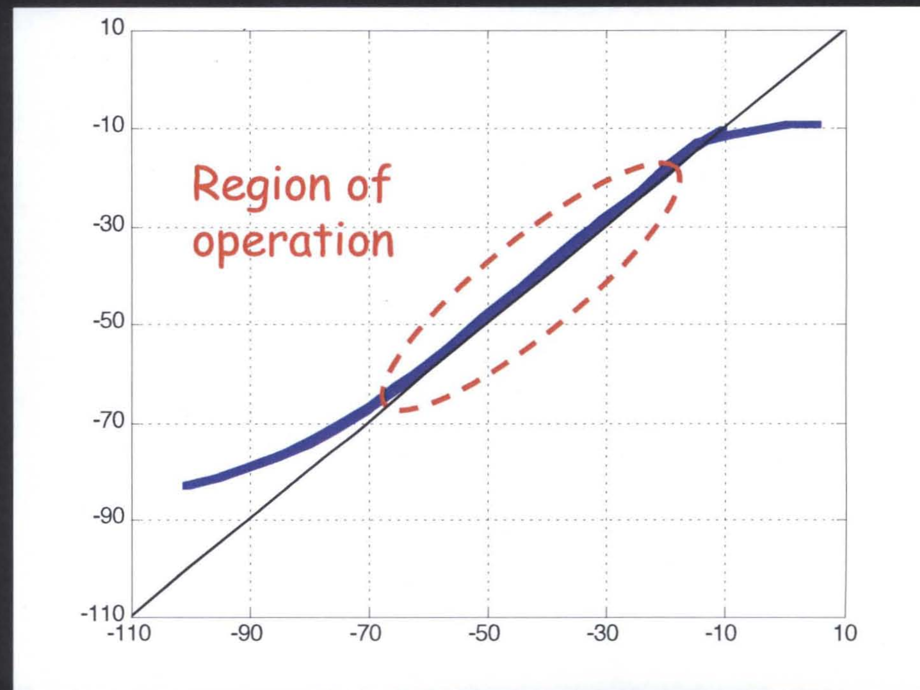
- These problems become even more significant and challenging to overcome at higher frequencies.
- An alternative approach is the use of high-Q compact resonant slots loaded with a PIN diode (i.e., modulated).
- Rapid sequential or parallel modulation schemes or tagging can be implemented while operating at relatively high frequencies.

Block Diagram

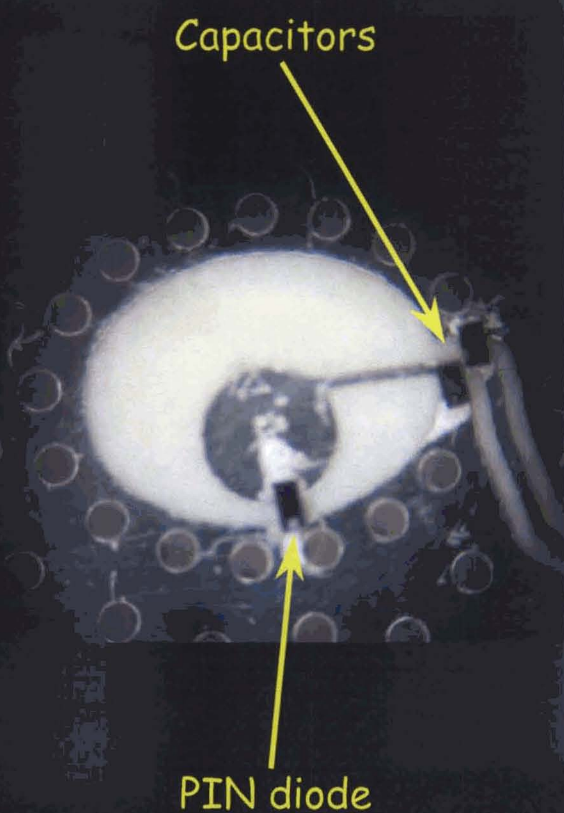


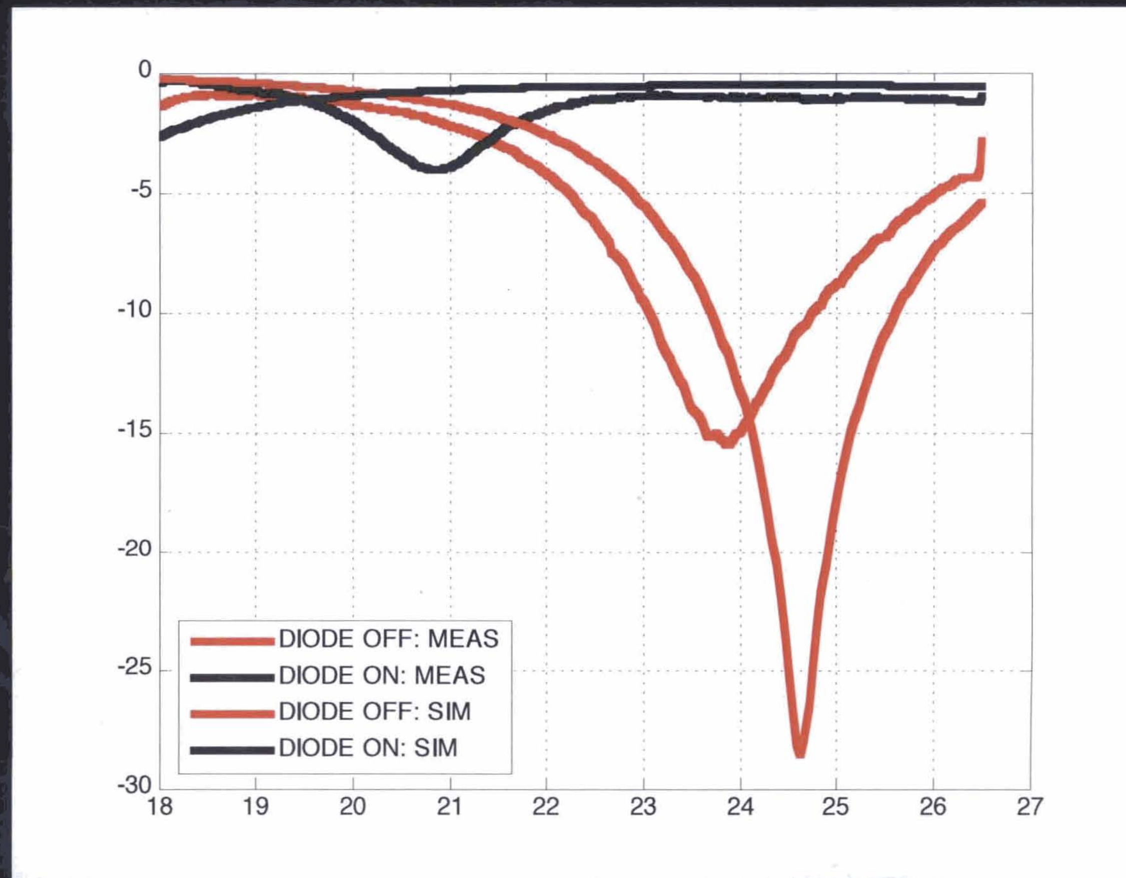
Design Requirements

- Large dynamic range
  - ✓ High sensitivity
  - ✓ Efficient elements
  - ✓ Large modulation depth
  - ✓ Minimum coupling
- High resolution,
  - ✓ Small elements (~λ/4)
  - ✓ Small Interspacing (sub λ/2)

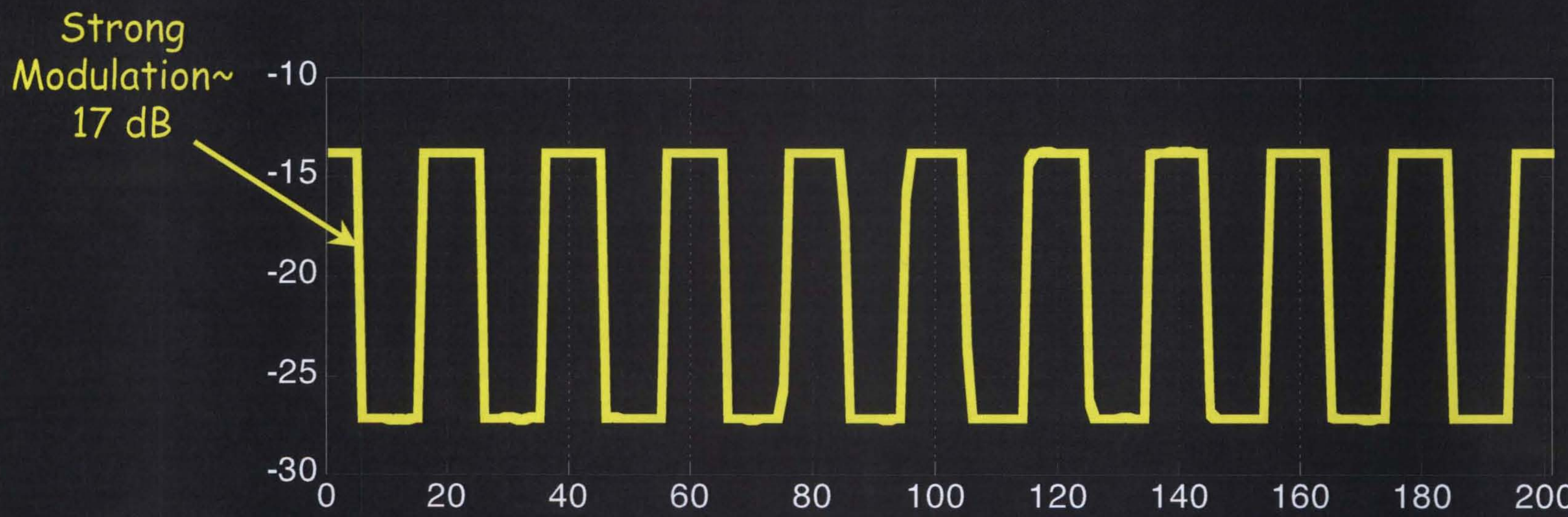


K-band PIN Loaded Resonant Slot



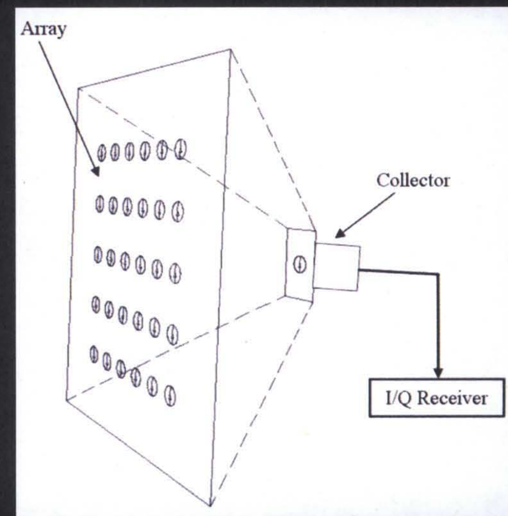


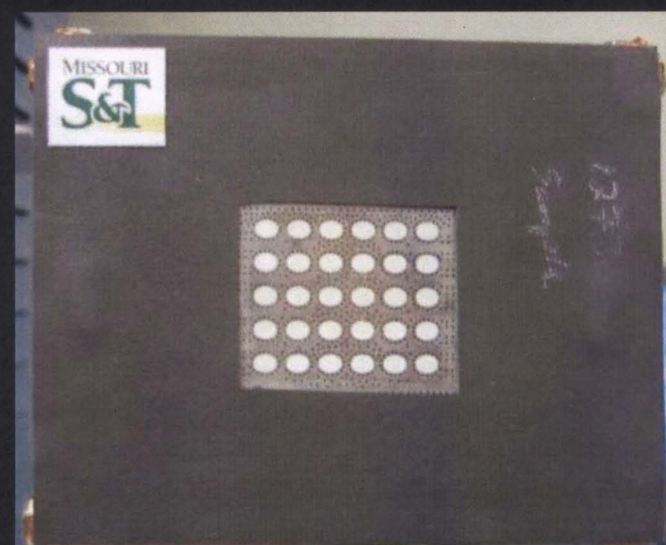
K-band PIN Loaded Resonant Slot



Prototype

- Frequency
  - 24 GHz
- Number of Elements
  - 30 (6 by 5)
- Element Spacing
  - $\lambda_0/2$
- Array Element
  - PIN diode-loaded resonant slot
- Pickup Type
  - Free-space collector (resonant slot)
- Correction
  - Referenced to plane-wave





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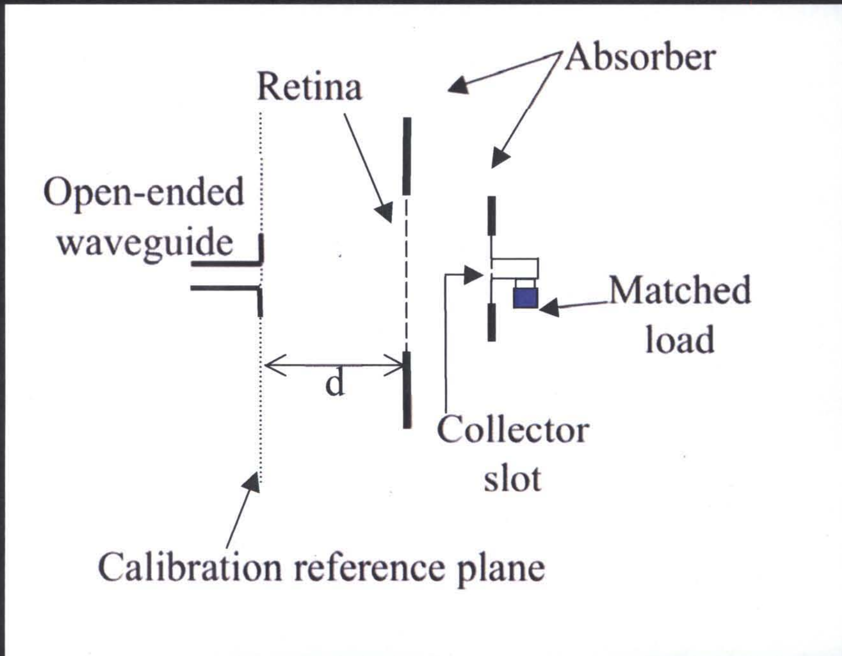
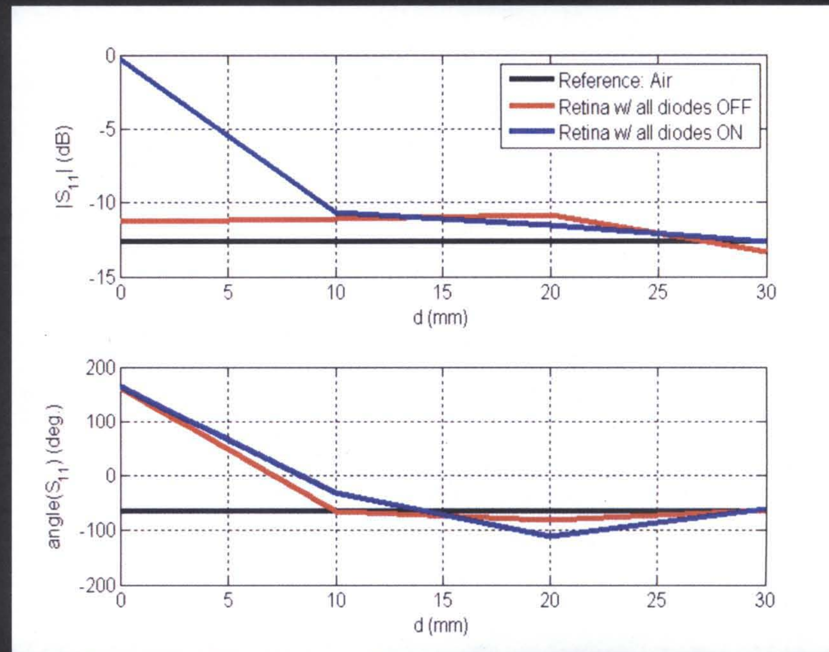
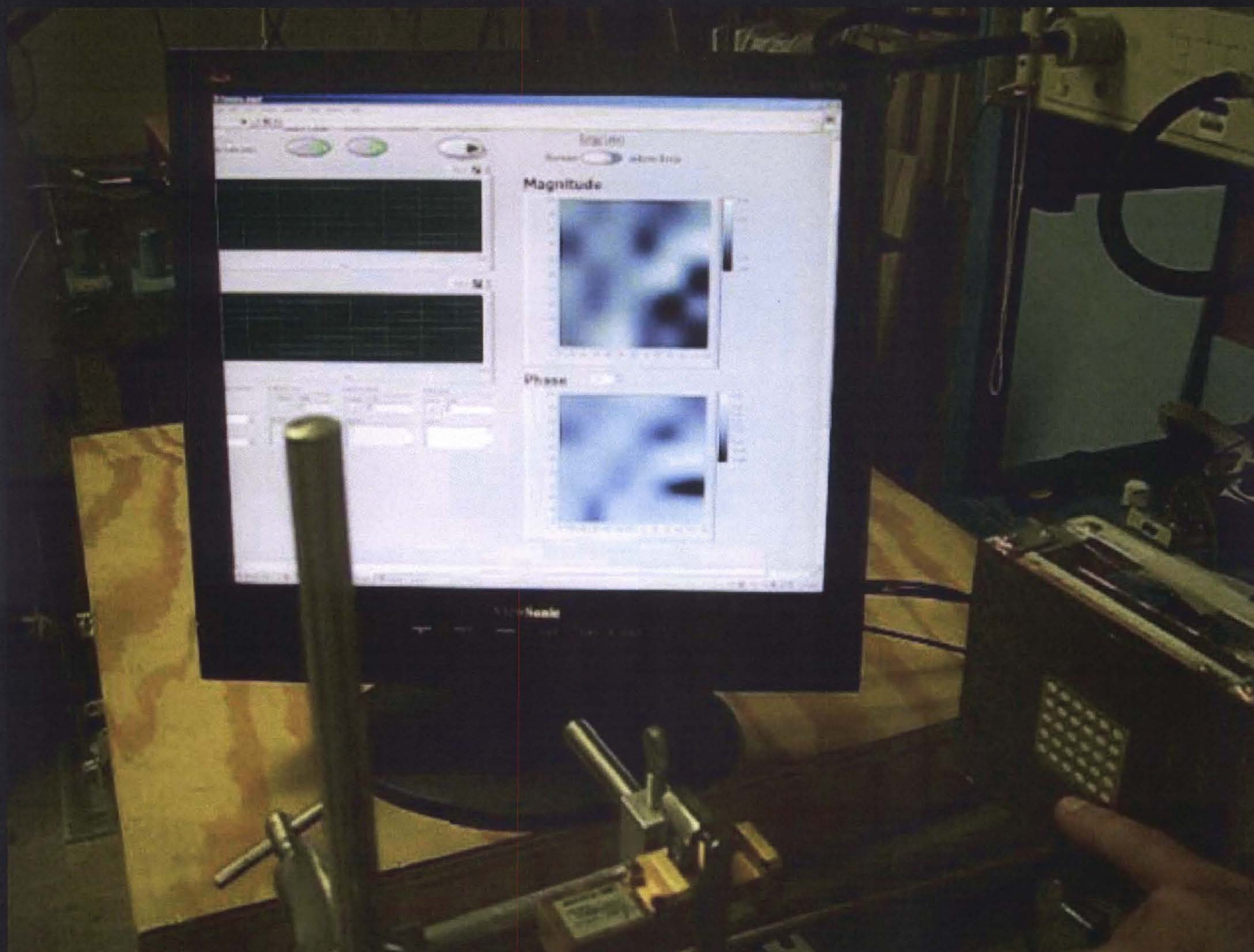
Retina Transparency





Real-Time Imaging

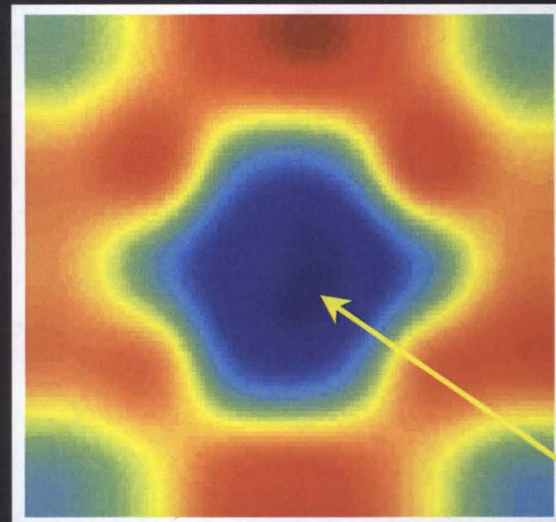


Transmission Mode

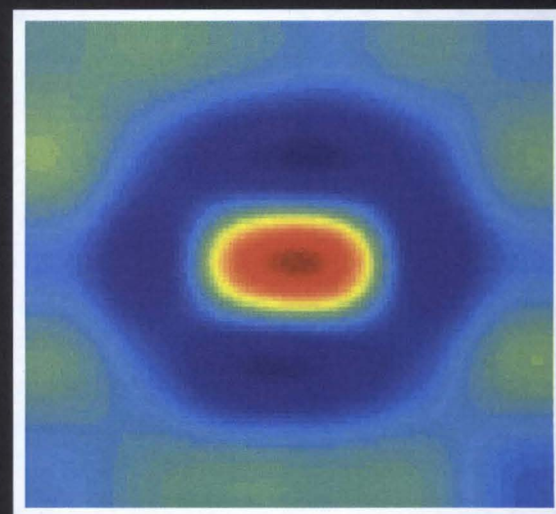
- Retina is used as a receiver.
- Object placed between retina and transmitter.
- Object is illuminated by a transmitter such as an open-ended waveguide.

Transmission Results

- Object
  - ✓ 4 mm-diameter metallic sphere
- Distance of object to retina
  - ✓ 5 mm
- Distance of transmitter to retina
  - ✓ 80 mm
- x20 super-sampled



Magnitude (dB)



Phase (deg)

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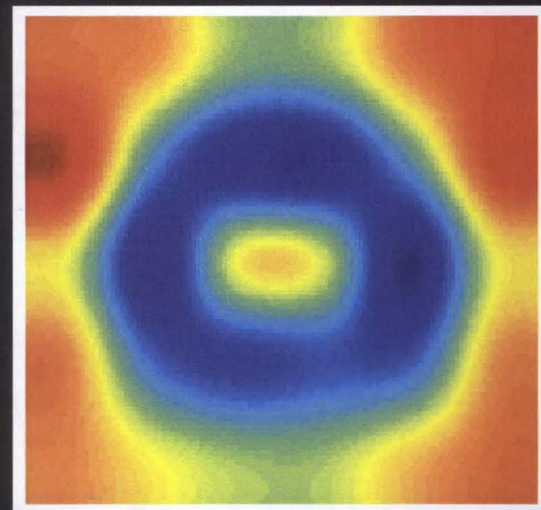
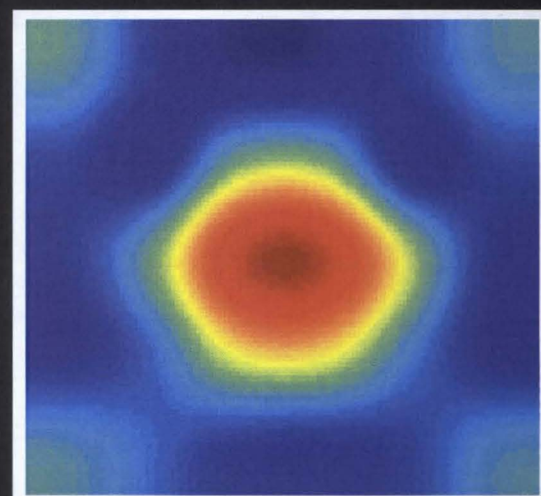
Transmission Results

- Object
  - ✓ 4-mm diameter metallic sphere
- Distance of object to retina
  - ✓ 12 mm
- Distance of transmitter to retina
  - ✓ 80 mm
- x20 super-sampled

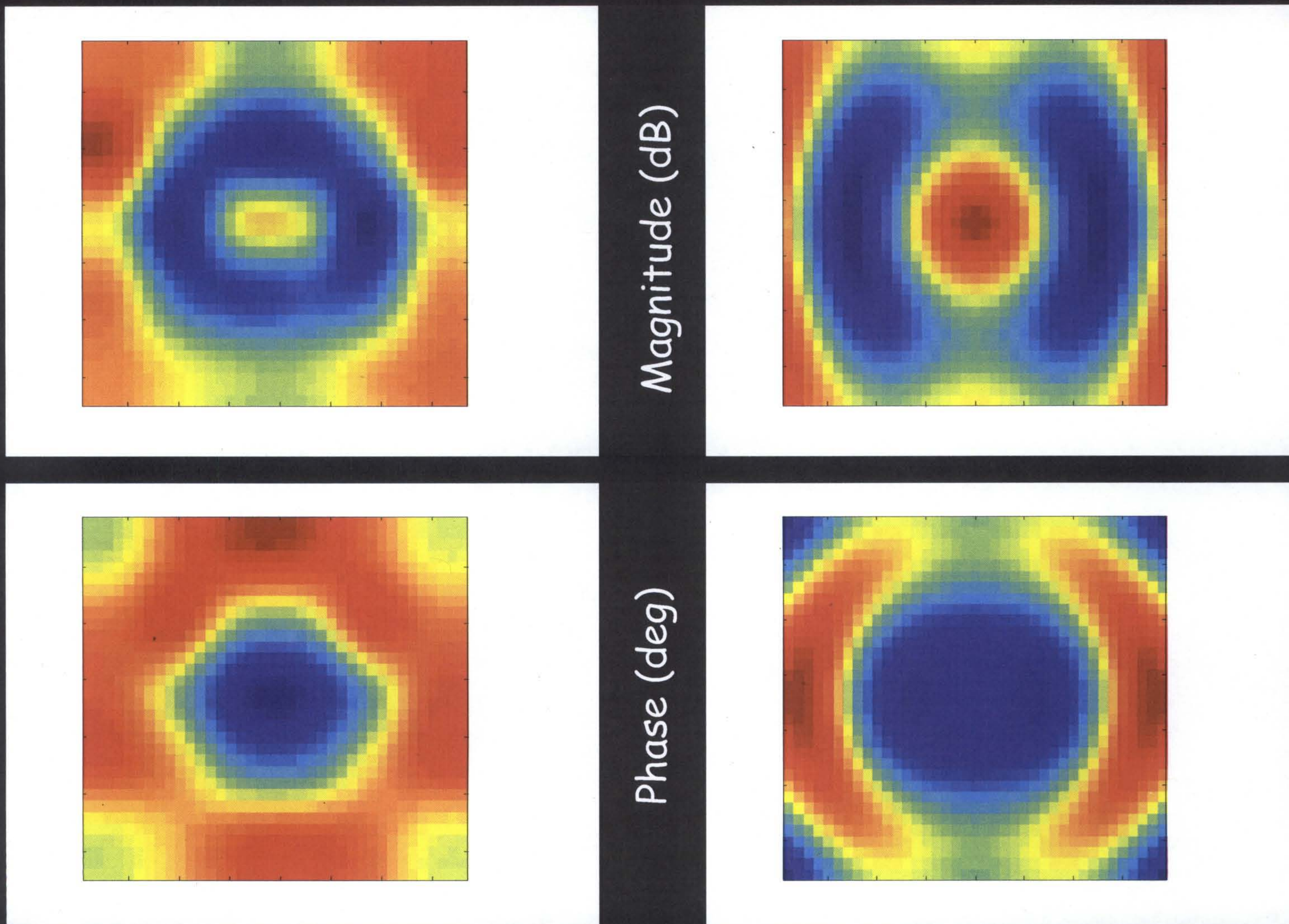


Magnitude (dB)



Phase (deg)

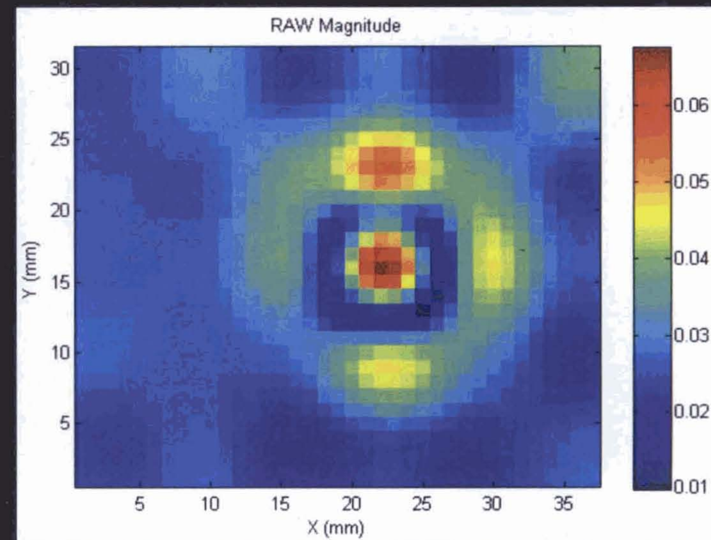
Measurement vs. Simulation

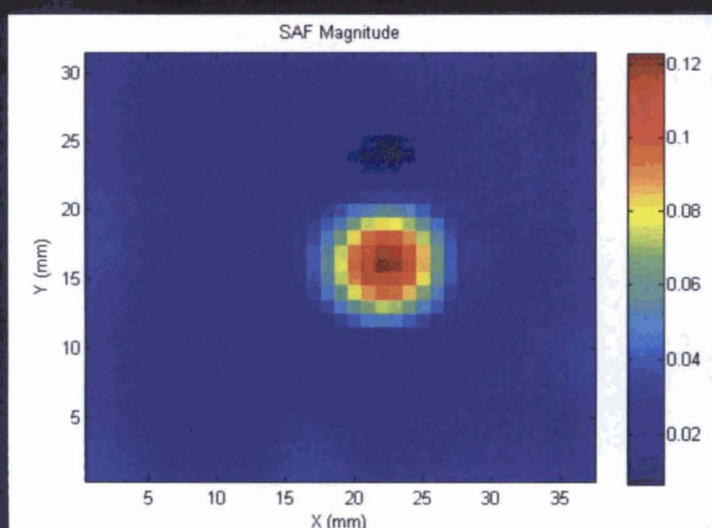


Measurement d = 12 mm Simulated

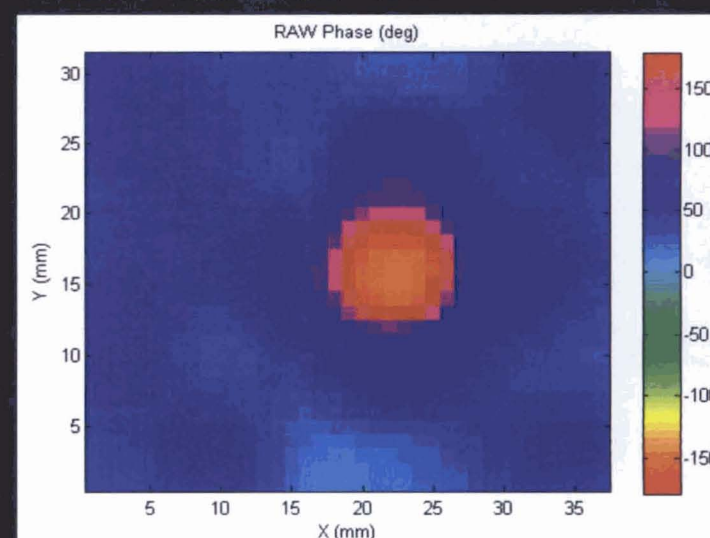
Reflection Mode

- Object
  - ✓ 10 mm-diameter metallic sphere
- Distance to retina
  - ✓ 10 mm
- x10 super-sampled





Synthetic Aperture Focused



Raw Magnitude & Phase

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Summary

- A novel 2D microwave imaging system at 24 GHz based on MST techniques.
- Enhanced sensitivity and SNR by utilizing PIN diode-loaded resonant slots.
- Specific slot and array design to increase transmission and reduce cross-coupling.
- Real-time imaging at a rate in excess of 30 images per second.
- Reflection as well transmission mode capabilities.
- Utility and application for electric field distribution mapping related to:
  - ✓ Nondestructive Testing (NDT)
  - ✓ Imaging applications (SAR, Holography)
  - ✓ Antenna pattern measurements